

MOS POWER COMPONENT WITH A REDUCED SURFACE AREA**Background Of The Invention**5 **1. Field of the Invention**

The present invention relates to a novel type of MOS-type semiconductor power component, this component being generally called a discrete component although several such components may be provided on the same chip, and/or they can be associated with logic circuits provided on the same chip.

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2. Discussion of the Related Art

Figs. 1A and 1B are a partial cross-section view and a top view of an example of the structure of a conventional multicellular vertical MOS power component.

This transistor is formed from a lightly-doped N-type layer or substrate 1 including, on its rear surface side, a heavily-doped N-type layer 2 (N^+). Conversely to what is shown, the N^+ layer may be much thicker than the N substrate. On the upper surface side of substrate 1 are formed P wells including a more heavily doped central portion 3 and a more lightly doped peripheral portion 4. Substantially at the center of the P wells is formed a heavily-doped N-type ring 5. Portion 6 of the P well external to N well 5 is topped with a conductive gate 7 insulated by a thin insulating layer 8. The upper surface and the lateral surface of gate 7 are insulated by an insulating layer 9 and the assembly is coated with a source metallization MS. The lower surface of the component is coated with a drain metallization MD. All the gates 7 are connected to a common gate terminal, not shown.

25 Fig. 1B is a top view of the structure without the gate and source metallization MS. The same elements are designated therein with the same references as in Fig. 1A.

For the simplicity of the drawing, each cell has been shown according to a square pattern. Other shapes are possible and currently used. When the source is negative with respect to the drain and the gate is properly biased, the current flows from the drain to the source, through the channel region in the direction of arrows I illustrated in Figs. 1A and 1B in a portion of the structure. Similar currents flow from each of the cells. These currents essentially flow vertically, whereby the MOS transistor is said to be vertical.

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A disadvantage of vertical MOS power transistors is their on-state resistance.

Indeed, practical considerations make it difficult to optimize the thicknesses of the various layers and regions according to the desired transistor characteristics. In particular, the thickness of N-type layer 1 must be sufficiently high for the component to have a desired breakdown voltage but must also be as small as possible to limit the on-state resistance of the component. N⁺ layer 2 is used to take an ohmic drain contact on the rear surface. Its thickness could be reduced to a few micrometers, but this would lead to too thin silicon wafer thicknesses (<100 μm), incompatible with current production tools. Very thick N⁺ layers 2 (of a few hundreds of micrometers) are thus used. This layer then introduces an additional series resistance that reduces the on-state performances of the transistor.

Another disadvantage of vertical components is that the channel width (perimeter of P wells 4) depends in particular on the surface of the semiconductor chip taken up by the transistor and cannot be increased beyond certain limits.

A MOS transistor has been described, only as an example of a vertical MOS-type component. The problems indicated hereabove generally relate to MOS power or vertical high-power components, for example, insulated-gate bipolar transistors (IGBT) and other voltage-control enrichment or depletion components, of MOS or Schottky-MOS type.

Summary Of The Invention

The present invention aims at providing novel types of semiconductor MOS power or high-voltage components enabling avoiding at least some of the above-mentioned disadvantages of vertical components, in particular increasing the active junction surface with respect to the surface area of the chip in which the component is formed, and reducing the on-state voltage drop.

To achieve these and other objects, the present invention provides a MOS power component in which the active regions extend perpendicularly to the surface of a semiconductor chip substantially across the entire thickness thereof.

According to an embodiment of the present invention, the contacts with the regions to be connected are taken by conductive fingers substantially crossing the entire region with which a contact is desired to be established.

According to an embodiment of the present invention, the conductive fingers are

metal fingers.

According to an embodiment of the present invention, the junctions or limits between regions are arranged in planes perpendicular to the main chip surfaces.

According to an embodiment of the present invention, the junctions or limits
5 between regions are formed of several cylinders perpendicular to the main chip surfaces.

A MOS power transistor according to the present invention alternately comprises a source region of a first conductivity type, an intermediary region, and a drain region of the first conductivity type, each of these regions extending across the entire thickness of the substrate, the source and drain regions being contacted by conductive fingers or plates
10 substantially crossing the substrate, insulated and spaced apart conductive fingers crossing from top to bottom the intermediary region, the horizontal distance between the insulated fingers being such that the intermediary region can be inverted when an appropriate voltage is applied to these insulated fingers.

According to an embodiment of the present invention, the conductive fingers
15 penetrating into lightly-doped N-type regions are surrounded with heavily-doped N-type regions.

An IGBT transistor according to the present invention alternately comprises a source region of a first conductivity type, an intermediary region, a drain region of the first conductivity type, and an additional region of the second conductivity type, each of
20 these regions extending across the entire substrate thickness, the source region and the additional region being contacted by conductive fingers or plates substantially crossing the substrate, insulated and spaced apart conductive fingers crossing from top to bottom the intermediary region, the horizontal region between the insulated fingers being such that the intermediary region can be inverted when an appropriate voltage is applied to
25 these insulated fingers.

According to an embodiment of the present invention, each of the conductive fingers is respectively connected to a source metallization, to a gate metallization, and to a drain metallization.

According to an embodiment of the present invention, localized metallizations
30 extend vertically between the source region and the intermediary region to form localized short-circuits.

According to an embodiment of the present invention, the insulated and spaced

apart conductive fingers are formed from conductive fingers crossing the entire thickness of the chip, the walls of which are oxidized and which are filled with doped polysilicon.

The foregoing objects, features, and advantages of the present invention will be discussed in detail in the following non-limiting description of specific embodiments in
5 connection with the accompanying drawings.

Brief Description Of The Drawings

Figs. 1A and 1B, previously described, are simplified cross-section and top views of a conventional vertical MOS transistor structure;

10 Fig. 2A is a simplified cross-section view of an embodiment of a MOS transistor according to the present invention;

Fig. 2B is a simplified top view of an embodiment of a MOS transistor according to the present invention;

15 Fig. 2C is a simplified top view of another embodiment of a MOS transistor according to the present invention;

Figs. 3A and 3B respectively are a circuit diagram and a simplified cross-section view of an assembly in parallel and in opposition of two IGBT transistors according to the present invention; and

20 Figs. 4A and 4B respectively are a circuit diagram and a simplified cross-section view of an assembly of a MOS transistor according to the present invention and of a fast diode.

Detailed Description

25 As conventional in the field of semiconductor representation, the various drawings are not to scale. Especially, in these various drawings, the lateral dimensions have been greatly exaggerated with respect to the vertical directions. Indeed, a silicon wafer currently has a thickness of from 300 to 500 μm – and greater thicknesses may be chosen for an implementation of the present invention – while patterns and vias may be defined according to dimensions on the order of from 5 to 50 μm .

30 Fig. 2A is a simplified cross-section view of a portion of a semiconductor wafer in which is formed an assembly of MOS transistor cells according to the present invention. The main surfaces of the component correspond to the upper and lower

surfaces of a semiconductor wafer, and the vertical dimension, the height of which is designated as e , corresponds to the thickness of the semiconductor wafer.

Figs. 2B and 2C are two simplified examples of top views of the structure formed in the semiconductor substrate, both corresponding to the cross-section view of Fig. 2A.

5 An elementary cell according to the present invention comprises a conductive finger 11 extending across the entire wafer thickness or across a major part of this thickness. Conductive finger 11 is bordered with a heavily-doped N-type region 12 (N^+), itself bordered with a P-type intermediary region 13, then with a lightly-doped N-type region 14, and a heavily-doped N-type region 15 serving as an ohmic contact recovery
10 with a conductive finger 16. Since conductive finger 11, regions 12, 13, 14, and 15 and conductive finger 16 extend substantially across the entire substrate thickness, and the junctions or limits between these elements are substantially vertical. Conductive finger 11 corresponds to a source metallization, region 12 corresponds to a source area, intermediary region 13 corresponds to the area in which a channel can be formed, region
15 14 corresponds to a drain area, region 15 corresponds to a drain contact recovery layer, and finger 16 corresponds to a drain metallization.

Fig. 2B is a top view of the present invention in an embodiment in which the conductive fingers are made in the form of vertical conductive plates extending in trenches made in a semiconductor substrate.

20 The embodiment of the MOS transistor gate according to the present invention can be better seen in Fig. 2B. This gate is formed by means of spaced apart conductive fingers 21 surrounded with an insulating layer 22 extending vertically in intermediary region 13. When a positive voltage is applied between gate fingers 21 and source finger 11, a channel forms in the vertical area of intermediary region 13 comprised between two
25 gate fingers, so that the MOS transistor becomes conductive between its source and its drain, and a current indicated by arrows I is likely to flow horizontally from the drain to the source. An enrichment MOS transistor has been described hereabove; in the case of a depletion MOS transistor, intermediary region 13, at least in the vicinity of the gate insulator, would be lightly doped of type N and the application of a voltage between gate
30 fingers 21 and source finger 11 would make the MOS transistor non-conductive between its source and its drain.

Conductive fingers 23 penetrating into all or part of the substrate thickness and

enabling establishing a short-circuit between intermediary well 13 and source region 12 have also been shown in Fig. 2B, which forms the equivalent of the short-circuit established by source metallization MS of Fig. 1A between N^+ ring 5 and the central portion of P well 3.

5 Fig. 2C illustrates in top view another embodiment of a component according to the present invention in which each MOS transistor cell exhibits a closed contour. Central source finger 11 is surrounded with an N^+ -type ring-shaped region 12, itself surrounded with a P-type intermediary ring-shaped region 13, an N-type ring-shaped region 14, and an N-type heavily-doped ring-shaped region 15 (N^+). In Fig. 2C, the structure has been shown as completely surrounded with a conductive ring 16. In
10 practice, this ring may be formed of a succession of conductive fingers close to one another. To simplify the representation, conductive fingers 23 have not been shown in Fig. 2C.

 The drain, gate, and source metallizations have not been shown in Figs. 2A, 2B,
15 and 2C. It should be understood that all gate fingers 21 are connected to a same metallization, all source fingers 11 are connected to a same metallization, and all drain fingers 16 are connected to a same metallization. Preferably, as in a conventional component, the drain and source metallizations are formed on two opposite surfaces of the semiconductor chip. According to an advantage of the present invention, the gate
20 metallization may, as chosen and as simply, be formed on the drain side or on the source side, which simplifies monolithic assemblies of components according to the present invention.

 The forming of a component according to the present invention will readily occur to those skilled in the art who may use conventional techniques for forming openings in
25 the form of vias or trenches, for doping from the openings thus formed, then for filling these openings with a conductor, for example, a metal, for example, copper, this filling being preceded or not by the forming of an insulating layer. It should be understood that, although terms via or finger are used in the present invention, these terms also encompass trench-shaped structures such as those in Fig. 2B or ring-shaped structures
30 such as metallization 16 of Fig. 2C.

 The above description essentially aims at the MOS transistor structure and the

order of the manufacturing steps may be modified.

As indicated previously, the present invention applies not only to a MOS transistor, but also generally to any MOS power or high-voltage component, for example insulated-gate bipolar transistors (IGBT) and other enrichment or depletion voltage-controlled components, of MOS or Schottky-MOS type. In particular, it can be simply
5 changed from the MOS transistor structure of Fig. 2 to an IGBT structure by replacing heavily-doped N-type layer 15 with a heavily-doped P-type layer.

According to an advantage of the present invention, the channel width per surface area unit is much greater than that obtained in a vertical diffused MOS transistor
10 (VDMOS) such as that of Fig. 1, as well as the total surface area of the drain of the cell assembly may be greater than the surface area of the chip containing these cells.

Another advantage of the present invention is that it is possible to form several components according to the present invention in the same semiconductor layer, with each of these components being easy to surround with insulating walls formed in any
15 chosen fashion. Examples of such assemblies will be given in Figs. 3 and 4.

Fig. 3A shows the diagram of an antiparallel assembly of two IGBT transistors according to the present invention comprising two main terminals T1 and T2 and two control terminals G1 and G2. In the following description, the main terminals of the IGBT transistor will be called the source and the drain to simplify the analogy with the
20 previously-described MOS transistor.

Fig. 3B shows a simplified example of the forming of such an assembly in which the same elements as in Fig. 2A are designated with the same reference numerals. The left-hand portion of the drawing shows an IGBT transistor comprising a source finger 11-1, surrounded with an N⁺ region 12-1, an intermediary region 13-1 crossed by gate
25 fingers that are not visible in the drawing. An N-type region 14-1 extends between region 13-1 and a P⁺-type region 32-1 that surrounds a drain finger 16-1. This assembly is separated by an insulating wall 31 from a structure arranged symmetrically with respect to this wall and comprising a drain finger 16-2 surrounded with a P⁺ region 32-2 and separated by a lightly-doped N-type region 14-2 from an intermediary region 13-2 in
30 which a channel is likely to form and into which gate fingers, not shown, penetrate. Intermediary region 13-2 is in contact with a heavily-doped N-type region 12-2 in contact

with a source finger 11-2. Although a single cell has been shown, it should be understood that each of the structures is formed of a cell assembly, as described previously. The source fingers of the cells located to the left of the insulating wall are solid with an upper metallization T1, as well as drain fingers 16-2 of the cells arranged to the right of the insulating wall. Drain fingers 15-1 of the cells located to the left of the insulating wall are connected to a lower metallization T2, as well as source fingers 11-2 of the cells located to the right of the insulating wall. Connections G1 and G2, of which it should be noted that they may easily be formed on the same surface of the component, have only been shown symbolically.

10 This structure has, as compared to monolithic structures assembling conventional vertical IGBT transistors, the advantage that the two IGBT transistors are perfectly symmetrical and that the transistors characteristics are also perfectly symmetrical.

The structures according to the present invention further enable associating MOS components such as described hereabove also formed with vertical junctions (perpendicular to the main substrate surfaces).

Fig. 4A shows an example of such an association, comprising a MOS transistor, TMOS, and a diode, D, the anode of the diode being connected to the drain of the MOS transistor. This circuit forms an element currently used in practice and difficult to integrate with conventional technologies.

20 Fig. 4B shows an embodiment of such a structure. In Fig. 4B, the left-hand portion is strictly identical to the left-hand portion of Fig. 3B except that the P-type region surrounding the drain region is replaced with an N⁺-type region to form a MOS transistor. The MOS transistor comprises a source finger 11, a source region 12, an intermediary region 13, a drain region 14, and a drain finger 16 surrounded with a heavily-doped N-type region 15. This assembly is separated by an insulating wall 32 from a diode structure comprising a cathode finger 40 surrounded with a heavily-doped N-type region 41 and separated, by a lightly-doped N-type region 42, from an anode finger 43 surrounded with a P-type region 44. The source finger of the MOS transistor is connected to a first main metallization M1. The gate fingers (not shown) are connected to a control metallization G1. Cathode finger 40 of the diode is connected to a metallization M2. The drain fingers of the MOS transistor cells as well as anode fingers 43 of the diode cells are connected to a metallization M3. In the shown example, metallization

M3 is on the rear surface side and metallizations M1, M2, and G1 are on the front surface side.

The various illustrated structures are likely to have various alterations and modifications, and those skilled in the art should note the alterations described for certain
5 embodiment apply to other embodiments.

On the other hand, many embodiments will readily occur to those skilled in the art, and will be possible according to the technical development, the forming of conductive fingers or of plates formed in trenches only being examples of possible approaches of the forming of structures with vertical limits or junctions.

10 It should be noted that, since more current per surface area unit of the chip may flow through a MOS transistor according to the present invention than through a conventional MOS transistor, more heat will be generated per surface area unit when the transistor is on (although the on-state voltage drop is smaller due to the possible optimization of the thickness of the reverse voltage hold layer). However, this heat may
15 advantageously be extracted by means of the through conductive fingers. Indeed, metal fingers have a heat conductivity from 2 to 3.5 times greater than the equivalent silicon volume. These fingers may take up a large surface area and, in particular, the peripheral "fingers" may take up the entire free surface area between elementary cells of a component.

20 Such alterations, modifications, and improvements are intended to be part of this disclosure, and are intended to be within the spirit and the scope of the present invention. Accordingly, the foregoing description is by way of example only and is not intended to be limiting. The present invention is limited only as defined in the following claims and the equivalents thereto.

25 What is claimed is: